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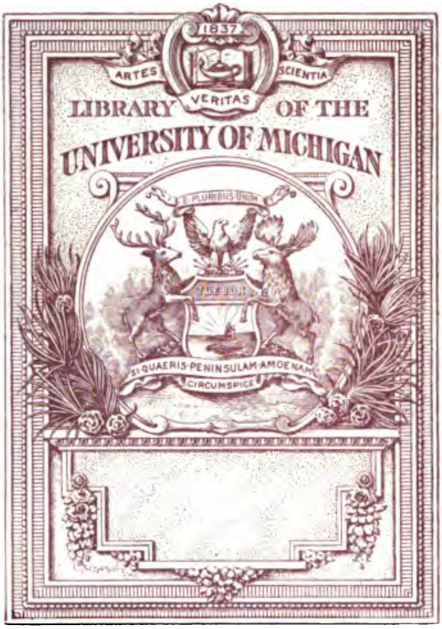
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A SYNOPSIS

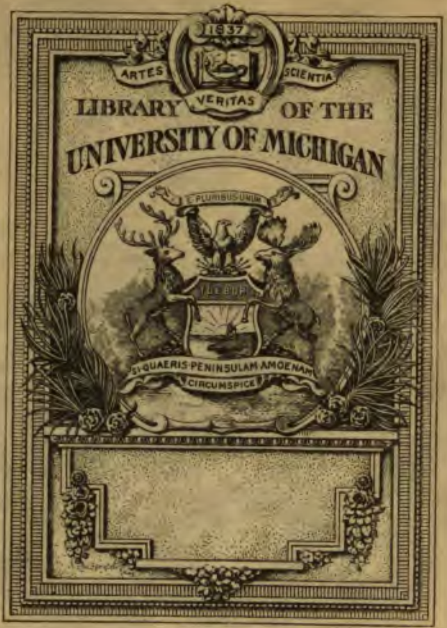
OF A COURSE OF LECTURES
ON

General Chemistry

PUT IN THE FORM OF QUESTIONS

S. L. BIGELOW

GEORGE WAHR
PUBLISHER AND BOOKSELLER
Ann Arbor, Michigan



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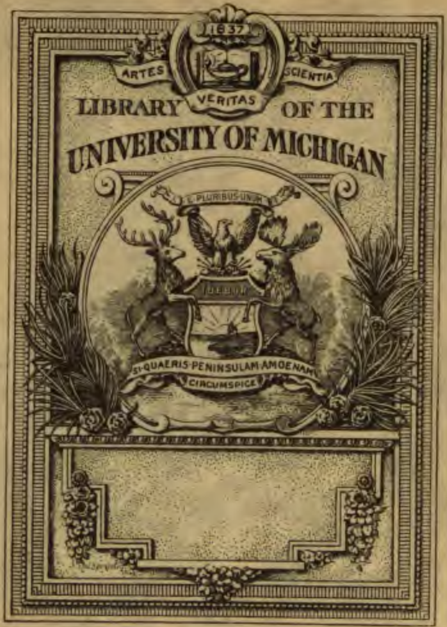

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PREFATORY NOTE.

The following questions constitute a synopsis of a course in general chemistry through the non-metals, and cover more than half of a lecture course planned to run through the year. A brief discussion of solutions and osmotic pressure, a study of carbon and of the metals completes the course.

As the majority of students take general chemistry soon after entering the university and before they have acquired proficiency in taking lecture notes, the purpose of the questions is mainly to indicate what is most characteristic, what should be noted and learned, about the substances investigated. Therefore these characteristic properties are, in most instances, asked for specifically. It will be noticed that the answers to some questions are contained in those immediately succeeding, but this is not thought to be a serious fault in a scheme intended primarily for directing a student's attention to what to study. If a student, shortly after a lecture, checks off in this pamphlet the points touched upon and, with the aid of his text, amplifies his own notes taken during the lecture, he will have a fair resumé of the subject It is hoped that the sub-headings in heavy type will enable the student to find readily what he is looking for even though the order of presentation in the lecture is different, and some topics are omitted.

A second purpose which these questions are intended to serve is to aid the instructors in recitation work. Where classes are so large that they must be divided into sections which recite to different instructors, such a list of questions facilitates the indication of the ground which has been covered in the lectures and in each quiz section.

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GENERAL CHEMISTRY

METHOD OF DESCRIPTION

When asked to describe a substance imagine that you have a sample of it before you and state all of its properties which you can determine by inspection. Next give the odor and taste, if these are at all characteristic or are generally used to aid in the identification of the substance. Then give the properties requiring instruments and manipulation for their determination, i. e., the physical-chemical constants (boiling point, freezing point, specific gravity), with reasonable accuracy if the substance is common or important and these constants fall within the range conveniently measured, otherwise an approximation or a relative statement such as that nitrogen boils at a somewhat lower temperature than oxygen will suffice. There should follow some statement of the solubility of the substance in water, and occasionally in other solvents as alcohol, ether and carbon bisulphide. The more strictly chemical properties are next to be considered. These are usually numerous and a selection should be made guided by the following rules: First, give some properties which bring out the analogy between the substance in hand and other, nearly related, substances. Second, give some properties characteristic of the substance as such, possessed by no other substance. Lastly mention some of the uses of the substance. Throughout the description be on the watch for, and call attention to, illustrations and applications of general and fundamental principles.

SOME FUNDAMENTAL CONCEPTS, UNITS AND LAWS

Define law, theory, hypothesis. Give examples.

Outline the correct method of thought.

What do we mean by a property of a substance. What do we mean by a substance. How many properties has one substance. Divide properties into two classes, essential and non-essential, for the study of chemistry, and give several concrete examples of each.

How many properties must be considered in order to establish identity between two substances. State the law here involved.

What do we mean by a process. Divide processes into two classes in such a way as to bring out the difference between chemistry and physics. What is a chemical reaction.

Define energy. How many forms of energy are there. Give one convenient classification of known forms of energy.

State the law of conservation of energy. Describe several laboratory experiments illustrating this law. To whom do we owe it.

Define matter. Are we sure it exists. Arranging our knowledge according to its degree of certainty what comes first, what follows, where does matter fall in the sequence. What two properties are always obvious when we say matter is present.

(A thorough knowledge of the metric system of weights and measures is assumed.)

Define weight and mass, emphasizing the difference between them. Give several illustrations of the fact that weight and mass are not synonymous terms. What is the unit of mass. Explain the centimeter-gram-second system of measurements. What is a dyne, an erg.

Which phrase is preferable, the conservation of matter, or of mass. State this law. Describe several laboratory experiments and several phenomena of nature on a large scale illustrating this law. To whom do we owe it. To what degree of accuracy has this law been proven by laboratory methods.

Name and define the three conditions of aggregation of matter. What other condition of matter may well be included in the list and be called a fourth condition of aggregation.

WATER

Give some of the essential properties of water. Divide these into physical and chemical. Make the list complete enough to establish the identity of water.

Physical Constants.

What are the three physical constants most used in chemistry.

Define specific gravity. What is our standard for the specific gravity of solids and liquids, of gases. Describe a hydrometer, a pyknometer, and the use of each.

Define the boiling point of a substance. Describe a method for its determination. Define the freezing point of a substance. Describe a method for its determination. Is any distinction to be maintained between the terms freezing point and melting point.

Chemical Properties.

What is the action of metallic sodium on water, on alcohol, on ether. Describe some new properties acquired by water after sodium has dissolved in it. What gas is evolved while sodium acts on water.

Give the details of two practical ways to resolve water into its components. (Electrolysis. Action of hot copper.) Define analysis.

Element, Chemical Compound.

Define element, chemical compound, mechanical mixture, solution. Give examples of each. Do we know how many elements there are. Do we know our elements to be the true elements.

OXYGEN

Give four practical methods for procuring oxygen. Describe the potassium chlorate and the barium peroxide methods in detail. What is the most characteristic property of oxygen. What is the test customarily applied to determine whether a given gas is oxygen or not.

Law of Definite Proportions.

Develope the law of definite proportions from experiments on water and on the preparation of oxygen. State the law. Apply it to the definition of a chemical compound.

Catalysis.

Define catalysis. Give an example of catalytic action.

Combustion.

What is combustion. Describe experiments. Is oxygen the only supporter of combustion. What name do we give to the products of combustion in oxygen. Give a few facts as to the importance and the abundance of this element.

Velocity of Reaction.

What do we mean by the velocity of a chemical reaction. Give an example of slow oxidation. What effect has temperature on the velocity of a chemical reaction. Define kindling temperature. Explain "spontaneous combustion."

THE GAS LAWS

What is the specific gravity of oxygen. Describe a direct method and also an indirect method for determining it.

What is meant by atmospheric pressure, and how is it measured. State reasons why we must adopt certain standard or normal conditions of pressure and temperature. What are these normal conditions.

State Boyle's law in words and also as a proportion. State Gay Lussac's law in words and as a proportion. (Combine these laws to the single equation $pv = RT$.) Gases do not follow the gas laws exactly. What is the nature of the variations we observe.

Temperature.

What are the fixed points on our temperature scales. (Centigrade and Fahrenheit.) Give the rule for the conversion of readings on one scale into readings on the other.

Absolute Temperature.

Show by means of a diagram just what we mean by the absolute zero and the absolute temperature scale. Mention phenomena of nature other than the behavior of gases pointing to an absolute zero of temperature at 273° centigrade.

What is the lowest temperature which has been reached and maintained for an appreciable time. How was this accomplished. Is it probable that we shall ever reach the absolute zero. What are some of the speculations concerning the condition of substances if brought to that point.

Examples in the Application of the Gas Laws.

100 c.c. of a gas at 18° and under a pressure of 740 mm. will occupy what volume under normal conditions.

A gas occupies 150 c.c. at 10° and under a pressure of three-quarters of an atmosphere. The pressure is increased to one atmosphere and the gas occupies 200 c.c. What is the new temperature.

A gas occupies 125 c.c. at 300° and under a pressure of 750 mm. The temperature is increased to 1000° absolute and the volume diminished to 100 c.c. What is the new pressure.

(Learn to do problems in gases by applying the laws successively as you can carry them in your memory, in the form of proportions, rather than by substitution in more complicated formulæ.)

HYDROGEN

Does hydrogen occur free in nature. Give several methods of preparation. What is the action of steam on red hot iron, on red hot coke. What is "water gas" and how is it made. Describe a Kipp apparatus. Name several substances used for drying gases.

State some of the most important properties of hydrogen, both chemical and physical. (Appearance, lightness, combustibility.)

What is the specific gravity of hydrogen when oxygen = 16.000. What is the specific gravity of oxygen when hydrogen = 1.000.

Explain the fact that in determining the specific gravity of one gas by comparison with another, it is not necessary to have them at normal temperature and pressure, but merely under the *same* conditions of temperature and pressure.

Is hydrogen to be considered as decidedly active chemically. Does it combine with oxygen at room temperature. Under what conditions and in what manner will it combine with oxygen. Describe the mechanism of an explosion and the cause of the noise.

Describe an experiment by which the water formed by the combustion of hydrogen may be collected and weighed.

Luminescence.

Describe the oxy-hydrogen blowpipe. What connection is there between the heat of a flame and the light emitted. Explain the conditions necessary for luminescence. Describe the lime light, the Auer von Welsbach light.

Occlusion.

Describe the phenomenon of occlusion of hydrogen by platinum and palladium.

Diffusion and Partial Pressure.

Describe an experiment illustrating the rapidity with which hydrogen will diffuse. State the law connecting the velocity of diffusion of a gas and its specific gravity. When will a gas diffuse and when will it cease to diffuse. (State in the form of a law.) What is meant by partial pressure. Illustrate by an example, the atmosphere for instance.

Law of Combining Volumes.

Describe an experiment by which the parts by volume in which hydrogen and oxygen unite may be determined experimentally. If the eudiometer tube contains 100 c.c. of hydrogen and 100 c.c. of oxygen before the explosion, and the apparatus is maintained at 100°, what will the total volume be after the explosion. Allowing the tube to cool to room temperature, what will it contain. Define the term synthesis.

State Gay-Lussac's law of combining volumes.

Oxidation and Reduction.

Describe one or two experiments illustrating the reducing power of hydrogen. What is meant by reduction, by oxidation. Is it possible to speak of oxidation or reduction with reference to a process in which oxygen takes no part.

Describe the method of calculating the composition of water by weight from the results of an experiment in which copper oxide is reduced by hydrogen.

Reversible Reactions.

What is the action of water vapor on hot iron, of hydrogen on hot iron oxide. What do we mean by the term, reversible reaction. Give some examples of such reactions. Are reversible reactions numerous or not.

The Law of Mass Action.

Do you know what makes a reaction go in one way rather than in another, or why it takes place at all. What was the old method of summing the matter up, given three elements, A, B and C, capable of forming the compounds AB and AC. Wherein is the summation faulty and incomplete.

What factors other than the natures of the substances themselves influence the chemical affinities existing between them.

What is the usual effect of an increase in temperature on the velocity of a chemical reaction. Is it possible for a change in temperature to wholly alter the course of a chemical reaction. (Think of the barium peroxide method of obtaining oxygen.)

What is meant by the concentration of a substance and how is it measured. What is the concentration of a solid. How is the velocity of a chemical reaction affected by a change in the concentration of one or of all the reacting substances. State the law of mass action. Illustrate the law by applying it to some definite case, for instance, to the reaction

Iron + water vapor = hydrogen + iron oxide.

Chemical Equilibrium.

Describe the condition of chemical equilibrium, demonstrating that it is not to be considered as a condition of rest.

Suppose some iron and water vapor to be sealed up in a glass tube which is then heated. Describe what happens within the tube up to the time when equilibrium is reached.

Suppose $A + B = C + D$ and, utilizing the above ideas, develope the formula for equilibrium as

$$\frac{\text{Concentration of A} \times \text{concentration of B}}{\text{Concentration of C} \times \text{concentration of D}} = \frac{k_1}{k_2} = K$$

HYDROPEROXIDE

By what other names is this substance known? Where, under what circumstances, and in what amounts, is hydrogen peroxide found in nature.

Describe in detail a method for making hydroperoxide. Is it possible to obtain it pure. Describe the appearance, color, condition of aggregation, specific gravity, solubility in water, of the substance.

What do we mean by a chemical test for a substance. Give the chromic acid test, the cobalt chloride test, the potassium iodide-starch test, the titanic acid test for hydrogen peroxide.

What is the effect upon a solution of hydroperoxide of adding some manganese dioxide, of adding finely divided platinum, gold, silver, sand, etc. What are the products of its decomposition. Is the manganese dioxide altered by the hydroperoxide. What is the name of actions of this sort. What precautions shoud be adopted if solutions of hydroperoxide are to be kept for a length of time. What is the strength of the solutions commonly sold at the drug stores.

Mention some of the uses of hydroperoxide. Is it an oxidizing or a reducing agent. Is it a bleaching agent, a disinfectant. What advantages has it for such purposes as disinfection and bleaching over other agents. Explain its action when used for cleaning old oil paintings.

Volumetric Analysis.

Describe a burette and a pipette and the use of each. Give the quantitative method for determining the amount of hydroperoxide in a solution by means of potassium permanganate. What is meant by the terms titration and end point. How are the results calculated. (Note that the fundamental principles here involved are those of all methods of volumetric analysis.)

The Law of Multiple Proportions.

Describe experiments by which the composition of hydrogen peroxide may be determined in parts by weight of its constituents. State the law of multiple proportions. Illustrate this law by a number of ratios as found in compounds of hydrogen and oxygen, of carbon and oxygen, and of carbon and hydrogen.

COMBINING WEIGHTS AND CHEMICAL SYMBOLS

Give the train of reasoning by which we are logically led through the facts expressed in the law of multiple proportions to ascribe characteristic numerical values to the elements, indicating the parts by weight with which they enter into combination.

Give a definition of combining weight.

Give some examples of chemical symbols, both of elements and of compounds, and explain their full meaning. Write a chemical equation and state the law which enables us to express a chemical process in the form of an equation.

Can we determine the combining weights of the elements from the results of analyses alone. What difficulty is encountered. Illustrate with a specific example.

What is taken as the standard, or unit of measurement, in expressing combining weights Give the reasons for adopting oxygen = 16.000 in preference to hydrogen = 1.000.

The Law of Combining Volumes.

What other law must we bring to our assistance in selecting the combining weights. Show that Gay-Lussac's law of combining volumes justifies us in ascribing to gases numerical values indicating the parts by volume with which they enter into combination. (Note the strict analogy between this reasoning and that from the law of multiple proportions.)

What volume is taken as the standard or unit of measurement in expressing combining volumes. What is its numerical value in c.c., in liters. How is this determined.

Why do we adopt for our standard a volume to contain two combining weight quantities of oxygen or of hygrogen.

What connection is there between the standard volume and the formula weight of an element or of a compound.

How does the standard volume assist us in selecting the most suitable from a series of possible combining weights? Illustrate by examples.

General question: From the laws of definite and multiple proportions and of combining volumes develope our present system of chemical notation, introducing no theory whatever.

THE MOLECULAR THEORY AND AVOGADRO'S THEORY

State the molecular theory. Give a definition of a molecule. Are we sure that there are such things as molecules. State Avogadro's theory.

What is meant by the molecular weight of a substance. What connection is there between the molecular weight of a gas and its specific gravity with reference to oxygen, with reference to hydrogen. How do we determine the molecular weight of a gas. How does the behavior of gases, as expressed by the gas laws, assist us in actual determinations of molecular weights.

Show how the molecular theory offers a plausible explanation for some facts, such as that a mixture of oxygen and hydrogen may be kept, practically unchanged, for an indefinite time, and yet may be made to react with explosive violence.

Illustrate by means of an example how a molecular weight determination enables us to select one from a series of ratios obtained by analysis, and how this aids in the selection of formulæ and the combining weights of the elements.

Are molecular weight determinations possible only with gases. Is the conception of molecules and molecular weights confined to substances in the gaseous condition of aggregation.

Theories as to Ultimate Constituents.

Give the fundamental assumption and the reasoning which leads to the atomic theory. To whom do we owe this theory. Give a definition of an atom. Why does the theory assert that all atoms of a given substance are of the same size and weight. To what difficultly imaginable consequence does the acceptance of the atomic theory force us.

What other theories have been advanced, concerning the ultimate constituents, in place of the atomic theory.

Give a short description of the vortex ring hypothesis and the premises upon which it is founded.

What phenomena are leading us to assume the existence of particles much smaller than the so-called atoms, and what do we call these particles.

OZONE

Where, when, and in what quantities is ozone found in nature. Describe the electrical method of preparation, also the method by means of phosphorus. How has pure ozone been obtained. What are some of its properties, appearance, approximate boiling point, stability, solubility in water.

In its chemical properties it is similar to what other substance. Demonstrate the similarity by citing a number of properties possessed in common. What is its action on potassium iodide starch paper, on indigo solution, on silver, on cork, rubber and many other organic compounds, on bacteria, on the lungs when it is respired.

What is the formula for ozone. Describe the experimental facts which cause us to select this particular formula.

Define the term allotropy. Give several instances of the phenomenon. What is the essential difference between allotropic forms. Define the terms endothermic and exothermic.

CHLORINE

Does chlorine occur free in nature. Name its principal compounds and discuss their distribution and quantity.

Give three methods for obtaining chlorine from its compounds. Which are suited for use on a commercial scale. Write the reaction representing the method by which it is obtained from common salt.

What is the molecular weight of chlorine. What is its combining weight, its symbol, its formula.

Properties of chlorine; appearance, specific gravity, solubility in water, odor, action on the organs of respiration. Is it readily liquified. Describe Faraday's experiment resulting in its liquefaction. What is the hydrate of chlorine and how is it made.

Is chlorine a supporter of combustion. Describe experiments with phosphorus, with antimony, with hot mercury, with turpentine. By what name are the products of the actions with the first three substances known.

Explain how it is that chlorine, containing no oxygen, acts as an oxidizing agent. Describe several experiments demonstrating its activity as an oxidizing agent. What is meant by the expression "nascent state."

Explain the fact that chlorine may be kept in iron cylinders without attacking the metal. [illegible]

Describe experiments illustrating the striking effect of light upon the reaction between chlorine and hydrogen. In what parts by volume do these two elements unite, and what is the name of the compound formed.

HYDROCHLORIC ACID

Does hydrochloric acid occur free in nature. Give two methods for its preparation.

Properties of hydrochloric acid; appearance, odor, taste, specific gravity with reference to oxygen = 32, molecular weight, formula. Describe an experiment demonstrating its great solubility in water. Explain the fact that it fumes in contact with the air. What are these fumes.

Draw a diagram containing a solubility curve. What values are laid off on the coördinates.

Is hydrochloric acid a supporter of combustion or combustible. What is its action on litmus. What is the action of its solution on magnesium, on zinc, on iron, on platinum, on gold.

When a solution of silver nitrate is added to a solution of hydrochloric acid what happens. What is a precipitate.

When a solution of hydrochloric acid is electrolysed, what gases are obtained and in what relative volumes.

When a solution of hydrochloric acid is heated what happens. What general rule have we concerning the solubility of a gas as affected by a rise in temperature. If the heating were protracted would anything remain.

Chlorides.

If we evaporate down some hydrochloric acid in which a metal has been dissolved do we obtain a residue. By what name is the residue known. How may we make a chloride.

Neutralization.

Describe the effect of adding more and more of a metal such as magnesium to some hydrochloric acid solution. What properties originally possessed by the solution have disappeared when no more magnesium will dissolve. Is this behavior typical of all acids. Define neutralization. What new substance is produced during neutralization. What substances other than metals may be used for the purpose of neutralization.

SODIUM HYDROXIDE

Give a method for the preparation of this substance. What is its appearance, solubility in water. Define the terms deliquescent, hygroscopic. Properties of the solution of sodium hydroxide; taste, feeling on the fingers, action on litmus, on a solution of phenol phthalein.

Describe experiments by which sodium hydroxide may be analyzed, and the parts by weight of its constituents may be determined. What is the simplest possible symbol for the compound according to this analysis. Are similar compounds known containing other metals. Name some of them.

What do we mean by the hydroxyl group. What do we mean by a radicle. Give the symbols and names of several radicles. Describe some properties common to many hydroxides. Distinguish between the terms base and alkali, defining each.

Write several reactions illustrating the process of neutralization of different acids with different hydroxides. What compound besides the salt is always formed.

Acidimetry.

What are indicators. Name some, describing their color changes. Describe the process of titration. Explain, by means of an example, the method of calculating the weights of different substances entering into a reaction.

One hundred grams of sodium hydroxide were neutralized with hydrochloric acid. How many grams of the acid were required and how many grams of each of the products were formed.

What do we mean by a normal solution,* a semi-normal, a 1-10 normal, 3 times normal solution. What do we mean by equivalent solutions.

How many grams of NaOH are in 300 c.c. of a 1-15th normal solution of that substance.

Twenty-five c.c. of normal NaOH solution required 60 c.c. of a solution of HCl of unknown strength to neutralize it. How many grams of HCl were present in one liter of the acid solution. What "normal" was the acid.

What is meant by a physiological normal solution of salt.

Define an acid by a list of properties common to all acids.

These properties common to all acids are ascribable to what portion of the compounds.

Define an alkali in the same general manner. To what part of the alkalies are these properties held in common to be ascribed.

Define a salt.

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* Molecular normal is meant unless the term equivalent normal is specifically used.

THE ELECTROLYTIC DISSOCIATION THEORY

Describe a property possessed by solutions of all chlorides but not possessed by chlorates.

Do such substances as alcohol, glycerine and sugar contain hydrogen. Do you consider them as containing hydroxyl groups. Will they give the usual acid reactions. Will they give the usual alkaline reactions.

Describe experiments to determine whether a solution is a good conductor of an electrical current or not.

What do we mean by electrolytes, and what classes of substances are electrolytes. What do we mean by direction of current, by electrodes, by anode, by cathode.

What chemical phenomenon always accompanies the passage of a current through a solution.

Define electrolysis. Give some instances of electrolysis.

Give a method for determining the direction of a current by means of some chemical change produced.

Give succinctly the main assumptions made by the dissociation theory. Define ion, anion, kation. By whom was the theory first proposed.

Is the existence of free ions in solution a matter of fact or of theory.

What ions do we consider as present when the following substances are dissolved in water: NaCl, HCl, HNO_3, KNO_3, NaOH. How do we indicate by symbol that a substance is present as an anion, as a cation. Can sodium exist in contact with water, can sodium ions. Explain.

In what way is the number of anions in a given solution related to the number of cations in the same solution.

Give Hess' law of thermo-neutrality and the explanation according to the dissociation theory.

Write a reaction representing double decomposition as it is usually written, then rewrite it in terms of the ions. Write several reactions according to the dissociation theory representing neutralization of an acid by an alkali.

Many acids when neutralized by certain alkalies show the same heat of neutralization. Explain this. Name a few acids and bases for which this holds, and others for which it does not hold. Explain the seeming contradiction.

BROMINE

Does bromine occur, free, in nature. State some facts concerning where and how it occurs and what the main source of supply is.

What is the technical method of obtaining bromine from its compounds. Give another, more commonly used laboratory method for the same purpose.

Describe bromine. (Include those properties which appear characteristic to you and which you could determine by inspection, given a little bromine in a test tube.)

What are the physical-chemical constants of bromine. (Boiling and freezing point, specific gravity, solubility.)

What is the specific gravity of bromine vapor. What is its molecular weight, its combining weight. Is bromine an oxidizing agent, a bleaching agent. What is its action with water. What are its physiological effects.

What is the action of bromine on most metals. The compounds of bromine and metals are called— Compare this action of bromine with that of chlorine on the same metals.

Compare the solubility of chlorides and bromides.

What are the physiological effects of bromides. To what part of the bromides may these effects be ascribed.

Hydrobromic Acid.

Compare the action of bromine and hydrogen with that of chlorine and hydrogen.

How may bromine be made to unite directly with hydrogen. When these substances unite what is the relation between the volumes of the interacting gases and the volume of the product. Name the product.

Can hydrobromic acid be made from a bromide and sulphuric acid, as hydrochloric acid is made from a chloride. Give a good practical laboratory method for making hydrobromic acid.

What is the appearance of hydrobromic acid. What are its physical-chemical constants. Its solubility in water: Its molecular weight: Its formula. Compare the properties of a solution of HBr with those of a solution of HCl.

The yellow color of a solution of HBr which has stood for some time is due to what.

IODINE

How does iodine occur in nature. What was formerly the main source of supply of iodine and its compounds. What is at present the main source of supply.

How may iodine be obtained from its compounds. What is the action of sulphuric acid on an iodide, with and without the addition of manganese dioxide.

What is the appearance of iodine. What are its physical-chemical constants. Solubility in water, in alcohol, in ether, in carbon bisulphide. What are the colors of the solutions. What is the color of iodine vapor.

Describe the phenomenon of sublimation.

Describe the test for the presence of iodine by means of starch. How sensitive is this test. Is it a test for an ion.

What is the action of iodine on metals. Describe what happens when mercury and iodine are heated together in a test tube.

What is the vapor density of iodine. What is its combining weight.

What charactesistic physiological effect has iodine?

Mention some of the uses of iodine and its compounds.

How may we tell chlorides, bromides and iodides apart.

Hydriodic Acid.

How may we prepare hydriodic acid. Is it obtainable by direct combination of the elements. What is its appearance: Its solubility in water: Its vapor density: Its symbol. What is the color of the solution when freshly prepared? After standing. Explain.

Is hydriodic acid an oxidizing or a reducing agent.

FLUORINE

Give the names and chemical composition of two rather common minerals containing fluorine.

Describe the apparatus and method by which Moissan obtained free fluorine.

State some of the properties of fluorine (appearance, color.) Is it readily condensed to a liquid. What is the peculiarity about its vapor density, and how do we account for this peculiarity. What is its combining weight.

What general statement may be made concerning its chemical properties. With what substances will it not combine.

What is its effect on HCl, on H_2O, on glass.

Hydrofluoric Acid.

How may hydrofluoric acid be made.

What is its appearance, its odor, its boiling point, its vapor density, its solubility in water. It fumes in the air, what are these fumes. Is it poisonous.

Give enough of its chemical properties to establish the analogy between it and the other halogen acids. What is its most characteristic chemical property. Does the water solution possess this property. In what may the water solution be kept.

THE HALOGEN FAMILY

On what basis do we divide our elements into "families."

Name the members of the halogen family in proper sequence. On what properties is this sequence based.

Make a table of these elements and their properties in such a way as to show the gradation of the properties. (Include combining weight, condition of aggregation, chemical activity, melting and boiling points, color.)

Cite instances of analogous gradations in the properties of series of their compounds.

What are Döbereiner's triads. Give examples of such triads.

What is Prout's hypothesis. How was it overthrown. For what reasons do we imagine that it may possibly reappear in some modified form. What is the fundamental idea expressed in the periodic system of the elements.

THE OXYGEN FAMILY

Name the members of the oxygen family.

Sulphur.

Where is sulphur found free in nature. Explain its existence in sedimentary rocks. Name the principal minerals containing sulphur, and give their chemical composition. How does sulphur occur in vegetables and animals?

By what two reactions was the free sulphur found in the neighborhood of volcanoes probably formed.

What is the effect of heating iron pyrites.

Describe the way in which the sulphur of commerce is obtained in Sicily.

How may it be purified. In what two forms is it brought upon the market.

What is its color, taste, odor, solubility in water, in CS_2.

What is its melting point. Describe all the changes observable as the temperature is increased up to its boiling point, and the nature of the substance after being poured into water from different temperatures.

Approximately what is the vapor density of sulphur vapor just above the boiling point, and what is the effect on the vapor density of raising the temperature to between 1000° and 1100°. Give a plausible explanation of this behavior.

What is meant by a polymorphous substance. By dimorphous, by tri-morphous. What other word is sometimes used to denote the same phenomenon. Distinguish between polymorphism and allotropy.

In how many different crystal forms does sulphur exist. Name the two important forms. Give methods for obtaining each of these two forms. How may one form be changed into the other. What is the essential difference between the two.

What is the temperature of change, and how may it be determined. Under what conditions is one form stable, under what conditions the other.

Give some of the chemical properties of sulphur. What is formed when sulphur burns. What occurs when a mixture of sulphur and iron are heated. What is its action in general on many metals. What is its combining weight.

Hydrogen Sulphide.

What is another name for hydrogen sulphide.

Where does it occur as such.

Tell how it may be made from its elements, from sulphur and water vapor. What is the most convenient way to make it.

Describe it, (appearance, odor, taste, boiling point.) What is its vapor density, its symbol, its solubility in water.

What are the products of its combustion.

A jet of air will burn in an atmosphere of H_2S. Is the combustion complete. State reasons for answer. Would a jet of oxygen burn in an atmosphere of hydrogen. What light does this throw on the constitution of a flame. What is a flame. Make it clear that the terms combustible substance and supporter of combustion are interchangeable.

Has a solution of H_2S any "acid" properties. What is the action of the oxygen of the atmosphere on the solution. What is the effect of boiling the solution.

How may H_2S be decomposed. What other gas, in contact with it, will destroy it.

What is the action in general of H_2S on metals, on solutions of salts of metals. What use is made of this in analytical chemistry. What, for example, are the colors of the sulphides of lead, zinc, antimony, arsenic. Are any of these color changes to be classed as delicate tests, *i. e.,* observable when minute quantities of the substances are present. Which may be selected as a convenient test for the presence of H_2S and how may it be applied.

Is H_2S to be called poisonous. What are its physiological effects.

Selenium.

Symbol. Combining weight. In connection with what other substances are its compounds found. In how many allotropic modifications is it known. Appearance of each modification. Describe it and enough of its compounds to establish the similarity between it and sulphur.

Tellurium.

Symbol. Combining weight. Does it occur in allotropic modifications. Describe its appearance. Give name, symbol, and a few properties of its hydrogen compound.

Make a table of the elements of the oxygen family showing the gradation of properties with ascending combining weights. Include in this table the symbols of the oxygen compounds and of the hydrogen compounds.

CHEMICAL AFFINITY AND VALENCE

What do we mean by chemical affinity. How far is it analogous to the attraction of gravitation, and at what points does the analogy fail. How far is it analogous to the attraction between electrically charged bodies and where does this analogy fail. Is it analogous to capillary force, to force of cohesion. What conclusion, then, must we make regarding the force called chemical affinity.

What is the most fundamental characteristic distinguishing it from these other forces.

Give a skeleton outline of an "electro-chemical" series of the elements. Name some called positive and others called negative.

Does a sharp line of demarcation exist between metals and non-metals. What properties are commonly used to classify substances as metals or non-metals. What are metalloids.

State a number of facts which prove there is a certain property conveniently called valence. Give a definition of what we mean by valence.

What do we mean by mono-, di-, tri-, tetra,- etc., valent. Name some elements of each class. How is the valence of an element measured, and what is the unit adopted.

May valence be considered as the quantity factor of chemical energy in a certain sense. Explain.

Discuss briefly the attempts to explain this property on the basis of lines of force, directions of preference, etc.

Draw several structural formulæ and state specifically the meaning of the lines connecting the symbols of the elements, limiting their meaning. What is a "saturated" compound, an "unsaturated" compound. Give examples.

What class of phenomena serve as the best justification for the use of constitutional or structural formulæ.

Give examples of metameric compounds.

Describe some of the difficulties met in attempting to apply rigorously the system of indicating each unit valence by a line. For instance, draw structural formulæ for such compounds as CO, ClO_2, NO, etc. Give examples of polymeric compounds.

Cite instances of variable valence, of molecular compounds.

COMPOUNDS CONTAINING OXYGEN CHLORINE AND HYDROGEN.

Hypochlorous Acid.

Formula. Preparation, using mercuric oxide, using sodium hydroxide and obtaining the acid from its salt. Use this as an illustration of a general method of forcing a reaction, which reaches a condition of equilibrium, to proceed to practical completion.

Has hypochlorous acid been obtained pure.

What are some of the properties of a water solution of hypochlorous acid. Explain the resemblance between these properties and those of a solution of chlorine in water.

What are the salts of this acid called, and what properties do they possess in common with the acid.

What is "bleaching powder" and what are some of its properties and uses.

How may we distinguish between a solution of a hypochlorite and a solution of chlorine in water.

Chlorine Monoxide.

Formula. Preparation from hypochlorous acid, from mercuric oxide.

Properties; appearance, stability.

Anhydrides of Acids.

What is an anhydride of an acid. Show the relation between an anhydride and an acid by means of structural formulæ. Has every acid its anhydride and every anhydride its acid.

Give the method of naming a series of four acids, each succeeding member being more oxidized than the last.

Does chlorous acid exist, do its salts.

Chloric Acid.

Formula. Preparation from hypochlorous acid, from chlorates. Utilize the latter method as another instance of the general method of forcing a reaction to go to practical completion and of obtaining the free acid from its salt.

How may chlorates be obtained from hypochlorites, directly from a solution of KOH, by electrolysis of NaCl.

Separation and Purification by Crystallization.

Given a solution containing for example KCl and $KClO_3$ how may they be separated by crystallization. What is meant by fractional crystallization. Explain fully by means of diagrams and solubility curves.

Give some properties of a water solution of chloric acid, (action of light, of heat, and of some oxidizable substance.)

Give some of the properties of the chlorates, particularly of the potassium salt.

Describe some experiments to demonstrate the oxidizing ability of the chlorates.

What are some of the uses of chlorates.

Perchloric Acid.

How may potassium perchlorate be made. How may perchloric acid be obtained from its salt.

What is the appearance of perchloric acid, and what is its most noteworthy property. What is its symbol.

The acid itself is unstable, its water solution is stable. Explain this by means of the dissociation theory.

Chlorine Dioxide.

How may chlorine dioxide be made.

What is its appearance, and what is its most striking property. Describe two experiments showing it to be a powerful oxidizing agent. What results when it is treated with NaOH.

Is it an acid. Is it the anhydride of an acid.

What is its formula, and can we write a structural formula for it, in harmony with our ideas of valence.

Free Energy.

What do we mean by free or available energy, by bound or unavailable energy. Arrange the sodium-chlorine-oxygen compounds in a series illustrating the loss in free energy. When such a series exists, what general law have we telling us which compound forms first.

Compounds of Bromine with Hydrogen and Oxygen.

Give the names and symbols of the known compounds containing bromine, hydrogen and oxygen.

How may we make hypobromous acid. How may we make a hypobromite.

Mention a property of the solution of this acid and its salts.

How may we make a bromate. How may we obtain bromic acid from this salt.

Give enough of the properties of these compounds to establish the close analogy between them and the corresponding chlorine compounds.

Compounds of Iodine with Hydrogen and Oxygen.

Give the names and symbols of the known compounds containing iodine, hydrogen and oxygen.

How may we make iodine pentoxide. What is its appearance. Is it the anhydride of a known acid.

How may we prepare iodic acid. What is its appearance. How may we prepare iodates from iodine, from $KClO_3$, from KI.

Explain the fact that iodine can drive out and replace the chlorine in $KClO_3$, although in most cases the action is the reverse and chlorine displaces iodine.

How may periodates be prepared. Give the symbol and appearance of periodic acid.

Explain why a substance to which the symbol Na_5IO_6 is ascribed is called a periodate.

What do we mean by "hydrated acids," by "the normal acid."

Compounds of the Halogens With Each Other.

Name some known compounds of the halogens with each other and containing no other elements. What is the action of these compounds with water.

Give a definition of hydrolysis. Give several instances of hydrolysis.

COMPOUNDS OF SULPHUR WITH OXYGEN AND HYDROGEN

Sulphur Dioxide.

Occurrence. Preparation from sulphur, from iron pyrites, from sulphuric acid, from a sulphite. Give a convenient test for it. Properties; appearance, odor, boiling point, appearance of liquid. Formula, molecular weight. Is it combustible.

Give an instance wherein it acts as an oxidizing agent and several instances of its reducing power. By means of what catalytic agents may SO_3 be obtained from it. Solubility in water. Is it the anhydride of an acid.

Sulphurous Acid.

Preparation. Is this more, or less active chemically, than sulphur dioxide. Give a plausible explanation of the difference based on the dissociation theory. May sulphurous acid be obtained pure. What is its formula.

Properties of water solution; what happens when air is run through it, when chlorine or bromine water is added to it, when $KMnO_4$ solution is added, when iodic acid solution is added. Is it an oxidizing or a reducing agent. Explain its effectiveness as a bleaching agent, as a disinfectant.

(Sulphite process of preparing wood pulp for manufacturing paper.)

Basicity of an Acid.

What do we mean by a monobasic, a dibasic, a tribasic acid. To which class does sulphurous acid belong.

Give the symbol and all the names for one salt in each of the series of salts of sulphurous acid.

How many grams of sulphur dioxide are required to make one liter of an equivalent normal solution of sulphurous acid; to make the same volume of molecular normal sulphurous acid.

Reactions of Solutions of Salts and the Strength of Acids and Bases.

Name some salts which, in solution, have no effect on litmus, others which show alkaline reaction, and some which show acid reaction.

Describe experiments dissolving zinc in equivalent solutions of hydrochloric, sulphuric and acetic acids and the rate at which hydrogen is evolved in each case. Describe experiments upon the conductivity of these same solutions. Explain the phenomena with the help of the dissociation theory. Apply the law of mass action to the solution of zinc in the above acids.

Define strong acid, strong base, weak acid, weak base. How may the strength of an acid be measured.

Apply our ideas of chemical equilibrium to our ideas as to the degree of dissociation in solution.

Explain the fact that the heat of neutralization of all acids is not the same.

Describe our present theory as to what occurs when a salt is hydrolysed in water solution. Is water itself dissociated.

Utilizing the theories involved in the last few questions, give a plausible explanation of the alkaline reaction of solutions of some salts and the acid reaction of solutions of others.

According to what scheme do we assume that dibasic acids and salts of dibasic acids dissociate in water solution.

What have we adopted as our unit "charge" (quantity of electrical energy carried by a monovalent ion). What connection is there between the amount of the charge and the valence of the ion. Illustrate by examples. How do we indicate different charges by symbol.

Sulphur Trioxide.

Preparation from sulphur dioxide, from a pyrosulphate. Properties, appearance when pure, when a trace of water is present.

Define polymer, polymerization.

Describe experiments illustrating the strong affinity of sulphur trioxide for water. Passed through a red hot tube what happens to it. Is it the anhydride of an acid.

SULPHURIC ACID

Does sulphuric acid occur free in nature.

Preparation from the anhydride, from sulphurous acid.

The commercial methods of preparation. This is a particularly comprehensive question and the answer should include the preparation from SO_2 with the aid of strictly catalytic agents such as platinum black and also with the aid of the oxides of nitrogen. Every essential step of the latter commercial process should be described. Glover tower, Gay Lussac tower, lead chambers. Reactions should be written indicating the probable course of the process.

Properties of the pure substance, appearance, odor, specific gravity. Note that there is a point of maximum specific gravity when water is added gradually.

Can the specific gravity of the resulting solution be calculated from a knowledge of the specific gravity of the pure acid and the water and of the volumes which are mixed. Can the concentration of the acid be calculated from the specific gravity of the solution.

What is the boiling point of sulphuric acid.

What is one of the most characteristic properties of sulphuric acid. Describe a dessicator.

What is the effect of sulphuric acid on wood, on a strong solution of sugar. Explain.

Concentrated sulphuric acid and copper are heated together. Write the reaction and point out what is oxidized and what reduced.

Tell of a few of the uses of sulphuric acid. Name some other substances, largely used, manufactured with the aid of sulphuric acid.

[Describe the Le Blanc process.]

What is Nordhausen, or fuming sulphuric acid, and how may it be made.

Name representatives of each of the two series of salts of sulphuric acid. According to what scheme do we suppose these salts to dissociate. What is "Glauber's salt."

Describe a test for sulphuric acid and sulphates. Explain what we mean when we say the tests of analytical chemistry are tests for the ions. Illustrate with several examples.

OTHER ACIDS CONTAINING SULPHUR, HYDROGEN AND OXYGEN

Make a list of these acids giving the names and formulæ. (Include the thio acids.) Tell of their relative importance.

Sodium Thiosulphate.

Preparation from a sulphite, from bisulphides, from a sulphide. Formula. By what other name is it often called. What is the effect of adding an acid to a solution of it.

What is its use in photography, in bleaching, in volumetric analysis. Write the reaction between sodium thiosulphate and iodine.

Sulphur Monochloride.

Preparation. Formula. Appearance and odor.

Technical use.

Are other chlorides of sulphur obtainable.

Acid Radicles.

Write a possible structural formula for H_2SO_4. What do we mean by sulphuryl. Write structural formulæ for, and name, two chlorine derivatives from H_2SO_4. What is the action of water on these chlorine derivatives.

What is thionyl. Give structural formula for a compound containing it. What is the reaction between this compound and water.

THE ATMOSPHERE

What is the color of the air. Explain the blue observed when looking upward on a clear day. Explain the redness of the setting sun.

Describe a method of measuring atmospheric pressure. What is the average atmospheric pressure at the sea level in millimeters of mercury, in grams per square centimeter.

Discuss briefly a few phenomena from which we may reach some conclusions as to the probable depth of the atmosphere.

How much air is there. Explain the simple method by which we make a close approximation of the total amount.

Composition of the Atmosphere.

Name all known constituents of the atmosphere. Name the four most important constituents. Describe three ways of determining the quantity of oxygen in the air. Describe a eudiometer.

45 c.c. air were mixed with 30 c.c. hydrogen and exploded. 66 c.c. of gas were left. What was the volume of oxygen in the original sample. How many c.c. of hydrogen were left after the explosion. What was the weight of water produced. (Assume the volumes were measured under normal conditions.) 25 liters of air, measured under normal conditions, were passed over hot copper turnings. What was the weight of copper oxide formed. What was the volume of oxygen absorbed (measured under normal conditions).

How may we detect the presence of carbon dioxide in the air and how may we determine its quantity.

One gram of barium carbonate corresponds to how many cubic centimeters of carbon dioxide measured under normal conditions. What connection has the carbon dioxide with the growth of plants, of animals. Is it normally present in "pure" air. Is it poisonous. Is it deleterious to health.

How is carbon monoxide made and what is its effect on living animals.

Vapor Pressure.

What may be said as to the amount of water vapor in the air. How does it get there. How may the amount present be measured. Define hygroscopic substance. Name three or four such substances.

What is meant by humidity. How is it expressed numerically?

What is meant by vapor pressure. What substances have vapor pressure. How may it be measured. Explain it by means of the kinetic theory.

How does vapor pressure alter with the temperature. Explain evaporation and the cooling effect of the process.

Give a scientific definition of the boiling point, concise and complete.

Draw diagram containing vapor pressure curves for water, alcohol and ether and show on the figure their boiling points under different pressures.

Explain the formation of clouds, of rain, of dew, of frost.

How may argon be obtained from the atmosphere. Mention some of its properties.

Give the composition of the atmosphere in parts by volume and also in parts by weight of nitrogen, oxygen, argon and carbon dioxide.

Explain the constancy of the composition of the atmosphere. Review the phenomena which tend to alter its composition.

Give several different proofs that air is a mechanical mixture and not a chemical compound.

What part does diffusion play in maintaining the constant composition of the atmosphere; in the ventilation of houses.

Henry's Law.

What is the solubility of oxygen in water, of nitrogen. How is the solubility altered by temperature, by pressure. State Henry's Law and given an example of its application. Extend the law to apply to mixtures of gases. What can you say concerning the solubility of air in water.

Liquefaction of Air.

What is meant by the critical temperature, the critical pressure. Distinguish between the terms gas and vapor.

Describe the principal features of a machine for liquifying air. What does liquid air look like. Approximately what is its boiling point. Discuss some of the possible uses for liquid air.

NITROGEN AND SOME OF ITS COMPOUNDS

Symbol, combining weight. How may pure nitrogen be prepared chemically. What is its most obvious chemical characteristic. How may compounds of nitrogen be obtained from the element. Have such methods any particular importance, present or prospective. Why.

Ammonia.

Preparation from its elements, from the oxides of nitrogen, from organic matter, from ammonium compounds. Origin of the name "spirits of hartshorn." What is our main source of supply at present. Describe a practical method of making "ammonia" of commerce.

Properties; appearance, odor, solubility in water. Parts by weight of its constituents, vapor density, formula. Is it combustible.

Properties of the solution, reaction with litmus. Give a number of reasons for assuming the existence of an ammonium ion. What is the symbol of the ion.

What is an amalgam. Describe a method of preparation, appearance and properties of ammonium amalgam.

Describe a delicate test for the presence of ammonium compounds in drinking water. Of what significance is this test concerning the use of water for drinking purposes. How may the amount of ammonia be determined quantitatively. What is the effect of heat on ammonium compounds. Describe an experiment proving that NH_4Cl dissociates to NH_3 and HCl.

If 15 liters of NH_3 be run through a red-hot tube what will be the volume of the resulting gases. Write the reaction. Is the decomposition complete.

What is the boiling point of ammonia. What is its critical temperature. Describe an artificial ice machine and how it works.

Why do we say ammonium hydroxide is a weak base.

Hydroxylamine.

How is it made. Properties; appearance, solubility in water. Formula. Properties of the solution; acid or alkaline. Give symbols of some compounds such as hydroxylamine hydrochlorate, nitrate and sulphate. Is it an oxidizing or a reducing agent.

Hydrazine.

A method of preparation. Appearance. Is the solution an oxidizing or a reducing agent. Formula. Has the solution an acid or an alkaline reaction.

Hydrazoic Acid.

A method of preparation. Appearance. By what other names is it known. Stability. Reaction of the solution with litmus. Write symbols of one or two nitrides.

OXIDES OF NITROGEN

Make a list of the oxides of nitrogen and of all known corresponding acids, giving both names and formulæ.

Nitrous Oxide.

A method of preparation. Properties, appearance, odor, taste. Is it readily condensed to a liquid. Is it soluble in water. Will it support combustion. Will it support life. Its use in medicine.

Nitric Oxide.

Preparation, by reduction of nitric acid with sulphurous acid, with copper. Properties, appearance. Is it readily condensed to a liquid Its solubility in water. Will it support combustion. Action with oxygen. Solubility in a solution of ferrous sulphate and color of this solution.

Nitrogen Trioxide.

Preparation. What reason have we for thinking the gas we obtain to be a mixture of two oxides of nitrogen. Give another name, sometimes used, for this compound.

Nitrogen Dioxide.

Preparation from lead nitrate. (Reaction.) Appearance, as solid, as liquid, as gas. Vapor density at different temperatures. Discuss this in connection with the possible formulæ.

What is the effect of a change of temperature upon chemical equilibrium. Why does raising the temperature cause the reaction to go in one direction and lowering it cause the reverse action. State Le Chatelier's rule.

What is formed when NO_2 is dissolved in water? Is NO_2 an oxidizing or a reducing agent. In what important process is this property utilized. Is it a supporter of combustion.

Nitrogen Pentoxide.

Preparation. Appearance. Stability. With water it gives what. Give a method of analysis from which its formula might be determined. Is this conclusive or is something lacking.

ACIDS CONTAINING NITROGEN, OXYGEN AND HYDROGEN

Give names and symbols of all known acids containing nitrogen, oxygen and hydrogen.

Which of the oxides of nitrogen are anhydrides of acids. Are the acids readily obtained from them by the usual method.

Nitric Acid and the Nitrates.

Where are the most important deposits of nitrates. What is saltpeter. What is chili saltpeter.

Preparation of nitric acid on a commercial scale. Write the reaction. The distillate is usually yellow. Why is this. How may this color be removed. How may it be avoided.

Properties of nitric acid. Appearance, odor, boiling point, freezing point, specific gravity, solubility in water.

Can pure nitric acid be obtained by distilling a water solution. Describe what happens when we start with a weak solution; with a strong solution.

Define constant boiling point mixtures and give two proofs that they are not chemical compounds.

What is the effect of light on nitric acid, of carbon, of silver, of copper, of zinc, of gold, of platinum. Is nitric acid an oxidizing or a reducing agent. When will it not dissolve aluminum and iron. Describe the ferrous sulphate test for nitric acid and nitrates, the diphenyl amine test.

What is aqua regia and what is its most characteristic property. To what does it owe this property.

What is the action of nitric acid on indigo, on a white silk ribbon, on the skin.

What is the reaction of lead or copper nitrate in solution, of sodium or potassium nitrate in solution. Explain.

What are some of the uses of nitric acid and the nitrates.

Nitrous Acid and the Nitrites.

Preparation of nitrites and of the acid. Has this acid been obtained pure. How may nitrites be told from nitrates. Are nitrites oxidizing or reducing agents. Formula.

Hyponitrous Acid and the Hyponitrites.

From what may these compounds be made. Appearance, stability. Formula.

PHOSPHORUS

Give names and symbols of several minerals containing phosphorus. Describe the method of obtaining phosphorus from bones.

What is the main use for bone charcoal.

Properties of yellow phosphorus, appearance, is it crystalline or not, hard or soft, melting point, specific gravity, solubility in water, alcohol, carbon bisulphide.

How may red phosphorus be obtained from yellow. Compare the properties of the red phosphorus with those of the yellow variety.

Describe experiments demonstrating the ease with which the reaction is started between phosphorus and oxygen. What compound is formed by this reaction.

Combining weight of phosphorus. Specific gravity of phosphorus vapor. Molecular formula.

Describe and discuss the phenomenon of phosphorescence. Is phosphorus an oxidizing or a reducing agent. Is it poisonous.

Describe delicate tests for the presence of phosphorus, first, based on phosphorescence, second, based on color imparted to flame of burning hydrogen.

Mention some uses for phosphorus. Describe the materials in a sulphur match, a parlor match, a safety match.

Phosphine.

Other names for the same substance. Preparation from phosphorus, from the phosphide of a metal.

Properties; appearance, odor, solubility in water. Is it poisonous. Vapor density, molecular weight and formula. Chemical properties, inflammability, result of combustion.

What are phosphonium compounds, method of preparing, formula, stability.

Liquid Hydrogen Phosphide.

Symbol, appearance, stability.

Solid Hydrogen Phosphide.

Symbol, appearance, stability.

Compounds of Phosphorus with the Halogens.

Give general formulæ for all compounds of phosphorus with the halogens.

Phosphorus Trichloride.

Method of preparation. Appearance, odor, formula. Write the reaction with water.

Phosphorus Pentachloride.

Preparation. Appearance, odor, formula. Draw a diagram with vapor pressure curves for the substance as a solid and as a liquid. What does this diagram illustrate concerning the boiling point and the melting point of the substance.

Discuss the vapor densities of the substance at different temperatures and explain the phenomena. Write the reaction between phosphorus pentachloride and water.

Phosphorus Oxychloride.

A method of preparation. Appearance, action with water. Formula.

Do phosphorus compounds with the other halogens exist and are they analogous to the chlorine compounds.

Compounds of Oxygen and Phosphorus.

Give symbols of four oxides. Tell of their relative importance. Which are anhydrides of acids.

Phosphorus Pentoxide.

Method of preparation. Describe each of the two allotropic modifications. Is the molecular weight known. What formula do we give it and what are our reasons for this selection. For what purpose is phosphorus pentoxide used in the laboratory.

ACIDS CONTAINING PHOSPHORUS, OXYGEN, AND HYDROGEN

Make a table giving the names and symbols of these acids and show their derivation from their anhydrides.

Orthophosphoric Acid.

Preparation from the anhydride, from phosphorus, from a salt of the acid. Which salt is commonly used. Appearance, odor, melting point. solubility in water. Upon heating orthophosphoric acid to a sufficiently high temperature, what is obtained.

How many series of salts are obtainable from this acid. Write the symbol and give the name for a characteristic salt of each series. What phosphates are soluble and what phosphates are difficultly soluble (insoluble) in water.

Describe the test for the presence of the orthophosphoric acid anion with a magnesium salt, with ammonium molybdate. The latter test is of particular importance in what branch of technical chemistry.

What is microcosmic salt, its formula. When a bead is made from it before the blowpipe of what does the bead consist. Describe the colors imparted to this bead by salts of cobalt, chromium, copper, manganese, iron, and nickel.

Pyrophosphoric Acid.

Method of preparing a salt of this acid, of obtaining the acid from this salt. Appearance of the acid, formula. How many series of salts might be expected from this acid; how many are known. How may pyrophosphoric acid be distinguished from orthophosphoric acid.

Metaphosphoric Acid.

Method of preparation. Appearance, melting point, formula. How many series of salts might be expected from this acid. Do the facts conform fully with the theory in the instance. With water what does it give. How may it be distinguished from ortho- and pyrophosphoric acids.

(Hypophosphoric Acid.)

Phosphorous Acid.

Method of preparation. Appearance. Melting point, formula. Is it hygroscopic. What does it give upon heating. How many series of salts should there be, how many are there. What are the salts of this acid called.

(Meta Phosphorous Acid.)

Hypophosphorous Acid.

Appearance, formula. Is it an oxidizing or a reducing agent. How many series of salts are there. What are they called.

Have these phosphorus compounds any connection with the life processes of animals, with the growth of vegetables.

ARSENIC

Combining weight. Symbol. Does it occur free in nature. Give names and formulæ of three or four minerals containing arsenic.

Method of obtaining the element from one of its minerals. Method of purifying arsenic.

Does it occur in allotropic modifications. Is it polymorphous. Is it to be called a metal or not. Discuss its melting point with reference to the phenomenon of sublimation.

How is arsenic affected by moisture in the air. At what temperature will it catch fire and what is the product of the combustion. Describe the odor produced.

Will it unite with halogens, with metals, with sulphur. Illustrate with symbols and names of a few compounds.

Arsine.

Give other names for this compound. Method of preparation. Appearance, odor, vapor density, formula. Is it poisonous. What substances are formed when it burns. Its stability as compared to phosphine. Describe Marsh's test in detail. Why is this test important. How do arsenic compounds which may be in the coloring matter of wall papers or carpets get into the air and thence into the body.

Give an illustration of the reducing power of arsenic.

Are arsonium compounds known.

Compounds of Arsenic with the Halogens.

Give general formulæ for compounds of arsenic with the halogens.

Arsenic Trichloride.

Method of preparation. Appearance, formula. Is it poisonous. What is its reaction with a small amount of water, with plenty of water.

Oxides of Arsenic.

What oxides are known.

Arsenic Trioxide.

By what other name is this known.

How is it prepared. Describe the appearance of the different modifications. Which form is stable at ordinary temperatures. Solubility in water. (Crystallization accompanied by emission of light.) What is the vapor density and corresponding formula at 800°, at 1,800°.

Describe an experiment demonstrating that it is readily reduced, another that it is readily oxidized. What is the product of the reduction, of the oxidation.

When dissolved in an acid, what does it form. When dissolved in the solution of an alkali, what does it form. Discuss its physiological properties, approximate fatal dose, acquired tolerance, supposed beneficial effects.

Arsenic Pentoxide.

Appearance. Solubility in water. Symbol. Is its molecular weight known.

Oxygen Acids of Arsenic.

Give names, symbols and derivation from their anhydrides of these acids.

Arsenious Acid.

Is this acid obtainable pure. How many series of salts has it. How may it be oxidized, and what is produced by the oxidation. What is its use in volumetric analysis.

Arsenic Acid.

Method of preparation. Appearance. Solubility in water. How many series of salts has it. With what reagents does it give precipitates similar to those obtained from phosphoric acid with the same reagents. How may arsenic acid be distinguished from phosphoric acid.

Compounds of Arsenic with Sulphur.

Give chemical names and symbols of the three known compounds of arsenic and sulphur. Give the mineralogical names for two of these compounds.

Arsenic Bisulphide.

What other name has this compound. Appearance, color.

Arsenic Trisulphide.

What other name has this compound. Method of preparation. Appearance, color, solubility in water, in acids, in hydrosulphides.

Colloidal Solution.

What is a colloidal solution. Give an example. Mention some of its properties. How may colloids be precipitated. Explain the formation of deltas at the mouths of rivers.

Arsenic Pentasulphide.

Method of preparation. Solubility in water, in acids, in hydrosulphides.

Sulpho-salts of Arsenic.

Give general method of making these substances. What is meant by a sulpho-anhydride. Give the symbols of potassium sulpho-arsenite, sulpho-arsenate, and sulpho-meta-arsenate. What occurs when the attempt is made to obtain the free acids from these compounds.

ANTIMONY

Symbol. Combining weight.

Describe the form in which it is found free in nature. Give the name and symbol of the principal mineral of antimony.

Give the method of obtaining antimony from the ore in some detail as a typical metallurgical process.

Appearance, structure, permanence in air. Will it burn. Action in contact with halogens. Solubility in acids.

Alloys.

Define this term. Are alloys chemical compounds. What relation does the melting point of an alloy bear to the melting points of its constituents. Do the properties of alloys correspond exactly to the properties of the constituents. What is type metal. What are the constituents of an alloy with a melting point below the boiling point of water. Name several useful alloys, naming the ingredients.

Stibine.

Symbol. Method of preparation. Is it obtainable pure. Appearance, odor. Is it combustible. Product of its combustion. Product of its decomposition by heat. How may an antimony "mirror" be distinguished from an arsenic "mirror."

Compounds of Antimony with the Halogens.

Give general formulæ for these compounds. Are they all known to exist.

Antimony Trichloride.

By what other name is this substance sometimes called. Preparation, appearance, symbol. Write the reaction between antimony trichloride and water. Name the resulting compounds.

Basic Salts.

Demonstrate by means of structural formulæ what is meant by a basic salt. Give formulæ for primary and secondary basic salts of antimony and hydrochloric acid. What is an oxychloride. Is SbOCl a basic salt.

What are the general characteristics of those elements which form basic salts.

Antimony Pentachloride.

Symbol. Method of preparation. Appearance. Action. with water.

Compounds of Antimony with Oxygen.

Give the names and symbols of the three known compounds.

Antimony Trioxide.

What is the mineralogical name for this substance. Method of preparation. Appearance. In how many crystalline forms is it known. Solubility in water, in nitric or sulphuric acids, in hydrochloric acid, in alkalies. Write the reaction between Sb_2O_3 and NaOH, and name the resulting compounds.

Antimony Tetroxide.

Describe the color changes this substance undergoes upon alternate heating and cooling.

Antimony Pentoxide.

Method of preparation. Appearance. Upon heating, what change occurs.

Acids of Antimony.

Write the symbols and give the names for a complete series of these acids derived from each of the two oxides Sb_2O_3 and Sb_2O_5.

Meta-antimonious acid has basic properties, explain. What is antimonyl. Write the symbol for antimonyl sulphate. Give the symbol and scientific name for tartar emetic.

Compounds of Antimony with Sulphur.

Give the names and symbols of the two sulphides.

Antimony Trisulphide.

The trisulphide appears as what mineral. How may it be prepared. Color. Solubility in solution of the sulphides of the alkalies.

Antimony Pentasulphide.

How may it be prepared. Color, solubility in water, in dilute acids, in solutions of the sulphides of the alkalies. Upon heating what occurs.

Are sulpho antimony acids and corresponding salts known.

BISMUTH

Symbol. **Combining weight.**

Does it occur free in nature. Give the names and symbols of three minerals containing bismuth.

Method of obtaining bismuth from its ores. What is a frequent impurity in bismuth so obtained. It must be removed from bismuth destined for pharmaceutical preparations. How may this be done. Properties of bismuth, appearance, structure, melting point (approximately). Is it affected by moist air. Upon heating strongly, what occurs. Is it soluble in HCl, in H_2SO_4, in HNO_3. Name two or three important alloys of which bismuth is a constituent.

Are compounds of bismuth and hydrogen known?

Compounds of Bismuth with the Halogens.

Give a general formula for the known compounds of bismuth with the halogens. Other compounds might be expected from the analogy with arsenic and antimony, but they do not exist. What would the formulæ of these compounds be.

Bismuth Trichloride.

Preparation. Appearance. Action with a little water, with much water.

Compounds of Bismuth with Oxygen.

Give the names and symbols of the four known oxides.

Bismuth Trioxide.

Preparation. Appearance. How does the method of preparation demonstrate that bismuth is a more pronounced metal than arsenic or antimony.

Give the symbol of bismuth hydroxide, of bismuth nitrate, of bismuth sub-nitrate. Give another and better name to the last mentioned compound indicating its derivation.

Give the symbol of neutral bismuth sulphate. What does this salt form with water.

What are the physiological properties of some of the bismuth salts and what is their use in medicine.

Does bismuth show any acid forming properties. In what compound.

Compounds of Bismuth with Sulphur.

Give the names and symbols of two compounds of bismuth and sulphur.

COMPARISON OF THE ELEMENTS OF THE NITROGEN FAMILY

Give the names, symbols and combining weights of the individual members of the family. Institute comparisons between the elements themselves and between their compounds, demonstrating their similarities and the gradation in fundamental properties. Put this information in tabular form.